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EFFECT OF VARIED PRESENTATIONS OF LABORATORY EXERCISES WITHIN PROGRAMED MATERIALS ON STUDENT ABILITY TO APPLY SCIENTIFIC PRINCIPLES TO PROBLEM SITUATIONS.

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AN EVALUATION WAS MADE OF THREE METHODS OF PRESENTING SCIENCE LABORATORY EXERCISES COMBINED WITH PROGRAMED INSTRUCTION. FIVE EXPERIMENTS WITH EIGHTH-GRADE STUDENTS WERE CONDUCTED TO EVALUATE TEMPORAL RELATIONSHIPS BETWEEN THE METHODS AND THE EFFECTS OF THE METHODS. MEASURES OF ABILITY TO SOLVE WORK AND ENERGY PROBLEMS WERE OBTAINED FROM SUBJECTS WHO OBSERVED, READ, OR RECEIVED ONLY PROGRAMED INSTRUCTION WITH LABORATORY EXPERIENCE. ALL METHODS PRODUCED SIGNIFICANT LEARNING GAINS. MULTIGROUP COMPARISONS BY ANALYSIS OF COVARIANCE SHOWED THAT EFFECTIVENESS OF PROCEDURES USED WAS HIGHLY DEPENDENT UPON THE TESTING INSTRUMENTS USED. NO SIGNIFICANT DIFFERENCE AMONG THE METHODS WAS OBSERVED. (WN)

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by

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CHAPTER ONE

INTRODUCTION

Some of the criticism directed at educational institutions in the United States reflect upon their rigidity. General statements about an inability to keep pace with a rapidly changing world and resistance to new and different approaches are rather consistantly being advanced. More specifically, a recent study designed to investigate the dynamics of instructional change within educational institutions in New York State resulted in the following statement by Dr. Henry Brickell (1961): "It should be noted here that much of the basic research into human behavior which underlies - or rather should underlie - teaching programs is carried out by psychologists, socialogists and other social scientists. Unfortunately, much of it lies unnoticed by people who are specialists in the process of education."

It is entirely possible that behavioral studies, in their broadest sense, may go unnoticed by educators. However, studies dealing specifically with human behaviors are seldom left unapplied for any extensive period of time. In fact, the very rapid assimilation of learning reinforcement theories, by educators, is a vivid illustration of reactions to a sound learning theory.

The conclusions resulting from basic research in learning behavior presented by B. F. Skinner (1954) in 1954 already have had far reaching effects. At that time, he states, "Some promising advances have been made in the field of learning. Special techniques have been designed to arrange what are called 'contingencies of reinforcement' - the relations which prevail between behavior on the one hand and the consequences of that behavior on the other - with the result that a much more effective control of behavior has been achieved."

The linear program evolved from Skinner's application of animal behavior to human learning has already been proven an effective device in a wide variety of situations. Theoretically it appears that an even greater array of specified behaviors can be effectively developed through appropiate application of 'contingencies of reinforcement' within programed instructional materials. The successful application of this procedure in developing behavior requires: 1) a definition of behavior, 2) construction of a linear program designed to develop the behavior, and 3) effecient procedures for evaluating the behavior.

It also appears that development of behaviors by means of the linear program, in subject matter areas currently in need of new and different approaches, would be a practical consideration. Thus, an area defined as a 'problem area' by educators and where failure to achieve stated goals is consistantly recognized, would benefit most significantly from the successful application of programed instructional materials. On the other hand, an educational endeavor currently being treated successfully and where contentment as to effeciency of procedures is recognized, would be hesitant about examining new techniques.

A PROBLEM AREA

It is commonplace to say that science is an organized body of knowledge and a method of applying that knowledge in the quest of further knowledge. Science stresses the ability to obtain new information - it teaches a discipline by which such information can successfully be obtained - it orders that which is known and uses it in search of new truths. From the foregoing, generally accepted descriptions, it is reasonable to generate two goals of general science instruction.

1) Students shall become acquainted with the organized body of scientific knowledge.
2) Students shall utilize the method of science in acquiring new knowledge.

Few authorities in the field of Education will dispute these goals of science education for our children. Similarly, it has frequently been advanced that these goals are not being attained effectively at all levels within the educational process. Specifically, Mallinson and Mallinson (1961) concluded that the quality of science instruction is low and that many teachers are poorly trained in science. Other authors are in general agreement with the conclusion that two possible contributors to the problems in science education are:

1) Ineffective training, especially of elementary and junior high school teachers in the area

of science.

2) Ineffective methods utilized by these teachers.

It tentatively appears that science education is an area that could benefit significantly from investigations involving application of programed materials. The specific behaviors to be developed, arrangement of learning activities within programed materials and evaluation of behaviors now become the major concerns.

The first major consideration involves the definition and development of specified behaviors. An examination of current science objectives provides little assistance. Confusion has been generated from the vague and loosely used phrase, 'problem solving ability' so frequently associated with the second general objective of science education. The term has been shown to be almost void of meaning by Guilford (1960). In his 'structure of intellect,' problem solving ability becomes closely allied with the entire broad scope of intellectual abilities. He states, "As in previous studies in which a number of problem-solving tasks were included, no general problem-solving factor was found." If his views are to be accepted, it becomes advisable to examine a more limited aspect of the ability rather than speaking of a general science problem solving ability. To identify various basic intellectual factors contributing to 'problem solving ability' would, of course be an ultimate aim of education. To identify one aspect of such an ability as it applies to science education and factors influencing such an ability would be a less ambitious undertaking, but hopefully a contribution.

The second major consideration in the attack on the problem involves the arrangement of activities to insure that the specified behaviors are adequately influenced. Again, confusion as to the appropiate methods of teaching science becomes apparent when we examine the theoretical foundations upon which current practices are based. Originating in the theoretical constructs of Thorndike and gaining impetus in the philosophy of Dewey we can find supporters of the, 'overt response-reinforcement,' requirement of learning. The activity type laboratory science programs that developed after the turn of the century probably owe their existance to these ideas. Although this procedure is still being widely recommended by a variety of agencies, the lack of empirical support and theoretical basis provide a rather tenuous foundation.

A second major method, the lecture-demonstration method, became popular in the thirties because a sudden increase in student enrollment made it finiancially impractical for all students to participate in laboratory situations. In an attempt to approximate the conditions of active experimentation, this method was approved as the best possible substitute.

More recently the theories of Mowrer indicate that overt actions may be unnecessary for many types of learning. Internalized actions and/or emotions may be key factors in the learning process and the lecture demonstration method may very well be equally as effective as laboratory methods.

THE SPECIFIC PROBLEM

From the vast array of potential factors influencing 'problem solving ability,' one dealing with the application of known information has been chosen as the primary concern in this study.

The specific problem involved factors effecting student behavior defined as an ability to apply scientific principles to new situations in a selected content area. Exposure to specified scientific principles, in the area of energy and work, has been accomplished by means of a linear program. The extent to which these principles can then be applied, as solutions to problems not previously encountered by the students has been used as the method of evaluation. It is reasonable to assume that such an ability may be dependent upon the students 'intellectual potential,' commonly defined as I.Q., as well as the students previous experience with the specific principles in question. Of the two factors effecting the ability, intellectual potential and prior experience, only the later has been a major concern in this study. Specific experiences have been presented to the student and the effect of these experiences on specified behaviors have been measured by two types of criterion instruments.

The utilization of programed instructional materials and their resultant effect upon specified behaviors has been investigated. The specific procedure by which students have acquired knowledge about laboratory type exercises has been designated as the independent variable.

Considerations affecting the approach to this problem have included experiences leading to the mastery of scientific principles on the part of students and a method of evaluating the degree to which the abilities have been mastered. Because of the lack of evidence indicating the superiority of any single method, a situation whereby three major methods can be compared has been established. The acquired ability will be measured in terms of specific problems relating to the specific principles learned and in terms of a 'general science problem solving ability.'

The junior high level was selected for this investigation for two reasons. The investigator's major experiences have been with this age group and students at this level have demonstrated an ability to benefit from instruction via programed instructional materials.

Further considerations dictating selection of experiences have included utilization of a unit of work in an area of science that would afford an opportunity to develop scientific principles by means of the major methods currently employed in junior high programs and utilization of a unit in which as few students as possible have had previous experiences. Such a unit appeared to be one in the physical sciences dealing with energy and work.

HYPOTHESES

The following hypotheses have been generated as the basic considerations arising from the specific problem previously stated. They are based on the assumption that teacher influence upon students, during the early part of the academic year, is held to a minimun when total student instruction is provided by programed instructional materials.

It is hypothesized that the specific methods selected for consideration, on the basis of their common usage, will have an effect upon student ability to apply scientific principles about energy and work to new situations. Because of individual differences and advantages and disadvantages within each method under consideration, it is further hypothesized that there will be no difference among groups on the ability in question.

A second series of hypotheses concerns the fact that a temporal relationship between activities and content will effect the ability in question. It is reasonable to assume that content, supported in time proximity, by experimental evidence will produce greater ability to apply the principles being learned. Content seperated from supporting experimental evidence, temporally, will decrease the total effectiveness of the experimental treatment. It is thus hypothesized that students performing experiments during their progress through the program will perform better on criterion instruments than students performing experiments either before or after the content portion of the program.

The following null hypotheses have been generated as the basic considerations arising from the problem perviously stated and are based on the assumption that teacher influence, upon students, during the early part of the academic year is held to a minimun when total instruction is provided by programed instructional materials.

1. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials which incorporate active participation in labobatory exercises throughout the program.

2. There is no significant gain in student ability to apply scientific principles to problem situations as a result of reading about laboratory exercises as they progress through programed materials.

3. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials accompanied by teacher demonstrations.

4. There is no significant gain in student ability to apply scientific principles to problem situations as a result of participating in laboratory exercises and then progressing through programed materials.

5. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials and then participating in laboratory exercises.

6. There is no significant difference in student ability to apply scientific principles to problem situations, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises, through descriptions or demonstrations.

7. There is no significant difference in student ability to apply scientific principles to problem situations, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises before, during or after progressing through programed materials.

8. There is no significant difference in student general science problem solving ability, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises, through descriptions or demonstrations.

9. There is no significant difference in student general science problem solving ability, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises before, during or after progressing through programed materials.

CHAPTER TWO

RELEATED RESEARCH

The problem has been stated as one in which the factors effecting student ability to apply scientific principles will be investigated. Student experiences with the specified scientific principles to be learned will be controlled by means of programed instructional materials. It therefore follows that relevant literature in the area of methodology in developing scientific abilities as well as evidence indicating an acceptable programing format should be surveyed. Results of this survey, as they bear upon the specific problem in question are presented in the two parts of this chapter.

Part 1 presents significant findings relating to comparisons of methods and how such methods effect a variety of scientific abilities. During the past decade, a majority of research effort in the area of science education, has been devoted to comparisons of Educational Television (ETV) and films to a variety of 'conventional' classroom procedures. These comparisons, as indicated in a review by Schramm (1961a) provide little help in arriving at a solution to the problem.

Part 2 presents findings relating to the internal variables of progremed instructional materials in an attempt to establish an empirical foundation for construction of the program to be utilized in this current investigation.

PART 1, RESEARCH RELATED TO METHODOLOGY IN SCIENCE TEACHING

Several individuals and agencies have attempted to provide periodic reviews of research in science education. In general, such reviews have established satisfactory minimal standards for those reports to be included during the specific time periods and for the stated topics under consideration. In an attempt to avoid duplication of effort, this current survey will rely heavily upon these cumulative offerings.

The significance of the role of science in general education has steadily increased since early 1900. General agreement as to curricular structure has been reached as well as a clear statment of aims and objectives. However, the methodology by which the more recent, less factual objectives are to be reached, still remains largely a matter of opinion.

Prior to 1950, a majority of the teaching method studies utilized factual, subject matter type criterion instruments. This, of course, could be expected, as factual recall was of major concern in the early part of the century. It appears though, that our advances in ability to state goals has far outdistanced our ability to achieve them. Evidence of this lag is apparent in the factual retention studies that have retained their role of importance as much as thirty years after general problem solving abilities and other concept related goals had become the accepted standard. Notable execptions to this generalization are found in those investigations concerned with laboratory courses, many of which attempted to measure performance skills related to manipulation of laboratory apparatus.

More recently, developments in methods of statistical analyses and further clarification of aims and objectives of science education has resulted in a transition in the type of study being conducted. Much more emphasis is being placed on the application of the scientific method, development of scientific attitudes and development of problem solving skills and/or abilities. (Skills and abilities have been used interchangably in research reports.)

A major difficulty entering into this later type of study is the prevailing concept of problem solving skill. Most authors deal with it as though it were an isolated, identifiable skill. Evidence from psychological testing centers however, has shown that such a skill cannot be isolated. (Guilford 1960) Rather, problem solving skill may very well be closely allied with the entire intellectual structure and may be composed of many factors within this structure. Because of the unwarranted assumptions required to define specific problem solving skills introduced by various investigators, this survey will retain the all-inclusive meaning most generally associated with the term.

Cunningham (1946) examined thirty-seven studies dealing with comparisons of individual laboratory methods versus lecture demonstration methods during the period, circa 1920-45. A majority of the studies reported involved physics or chemistry and were initiated because of concern with rising laboratory costs resulting from increased enrollments. Fifteen studies gave attention to time required by each of the two methods and all found time savings in favor of the lecture demonstration method. Time saved varied from one-fifth to one-half. Twenty of the twenty-eight studies concerned with immediate recall abilities reported in fovor of the lecture demonstration method, six in favor of individual laboratory method and two showed no difference. Of seven studies reporting on student interest, three were in favor of the lecture demonstration and four in favor of the individual laboratory method.

In general, Cunningham concluded that both methods should be used to provide a greater variety of experiences for students. Specifically, he stated that individual laboratory skills are developed most efficiently by a laboratory method while the lecture demonstration method is superior for ordinary written information.

Buck and Mallinson (1954) examined findings of elementary science research studies conducted during the period of 1929-52 with the aim of presenting reasonable conclusions based on their general findings. They reported that studies relating to learning showed a noticable lack of concern with problem solving abilities and attitudes. Another observation dealt with the fact that a great amount of literature had been devoted to the use of laboratory exercises at the elementary level, but unfortunately much of it was of an 'opinion' nature rather than accounts of research activities. A significant conclusion reached by them concerned the fact that scientific investigations of various practices must be conducted before improvement in teaching methods can occur.

Florence Weller (1933) stands out during this period with a study designed to investigate problem solving ability. She concluded that the material of an elementary science program provides the means for developing desirable attitudes and skills in problem solving if attention is focused in this direction. However, the study involved the use of a multiple response criterion instrument involving the observation of data, drawing a conclusion from the observation and then verifying the conclusion. It is doubtful that such an instrument measured what would more recently be labeled as a problem solving ability. It would appear more likely that an increase in awareness of logical consequences were developed by students which may very well be an important factor in problem solving ability. This study is a significant deviation from the norm of this period.

Smendinger (1960), in a more recent study, verified Weller's findings that science problem solving ability can be improved in a normal science program without a corresponding loss of factual content acquisition.

By 1950 science educators were able to conclude rather definitely that the method of instruction in science made little or no difference if attempts were being made to measure factual recall of subject matter. They were also able to state, rather positively, that laboratory skills could be taught by a method invloving individual laboratory participation. Also, during the fifties, a gain in sophistication in understanding research activities related to learning science at the elementary and junior high level was made. Not only is there an apparent decline in factual recall type studies but more critical comments about ineffective and superficial research efforts can be found. Anderson (1954) states, "There is a tendency to give far too little attention to the validity of procedures and evaluation instruments." Smith (1955) adds, "A dearth of controlled, statistically analyzed research was apparent and disconcerting." And finally, Boeck (1956) reached the conclusion, "Some new approach is needed to children's interest and development of concepts if further studies are to be rewarding."

As late as 1960 science educators were still floundering as evidenced by a comment in the 1960 edition of Encyclopedia of Educational Research. "In many instances, the studies in science education have failed to yeild significant results because the criterion measures or examinations used have been invalid or unrealistic or have failed to sample adequately the skills or understandings under study." It is unfortunate that such an amount of effort has gone into this area of research and yet so little has been contributed to the field of knowledge of science instruction.

Mallinson and Mallinson (1961), in summarizing research in elementary science instruction, reached the conclusion that much has been done in the way of survey studies but little has been done in the 'how-to-do-it' category. This finding would seem to be indicative of an attitude toward the labor involved in establishing rigorous conditions required for original research.

Some significant results in recent investigations indicate that organization of learning activities may have some effect upon problem solving ability. An inductive approach as contrasted with several other approaches appears to be superior for development of scientific attitudes, problem solving ability and application of the scientific method. Organization centered around concepts rather than traditional topical presentations seems to provide for significant gains in problem solving abilities. In general, the deductive approach has been found to be less useful than the inductive approach for 'science method' oriented studies. (Boeck, 1953; Buck, 1954; Meredith, 1963; Scott, 1960; Sister Erestine Marie, 1962)

Classroom performance of a series of nine experiments was no different in promoting content learning than the text-recitation procedures used in an investigation by Kiszka (1958). Boeck (1960) reports 'no significant difference' between reading and demonstration techniques for developing understanding of mirrors and mirror images. Carpenter (1963) however, reported a significant difference between classroom demonstration and experimentation when compared with a text-recitation method. The demonstration and experimentation produced higher criterion scores for the entire group and was also significantly better for slower students than brighter students.

Carpenter (1959) found that a greater degree of interest was displayed by students toward a problem solving approach or demonstrations as compared with students who read and discussed identical type material.

Butts (1962) found that mere manipulation of data had no effect upon concept development. In an interesting investigation he provided students with the opportunity to complete activities without verbal explanations. Successful manipulation of the data had no effect on understanding of the scientific principles upon which the data was based. Similarily, Owens (1951) found that students, presented with the opportunity to discover applications of data, performed no better on a test of ability to recognize and apply scientific principles than students who had no similar discovery opportunity.

An unresolved problem appears to be a clear definition of problem solving behavior. It has been demonstrated that the 'problem solving ability' so frequently alluded to in literature dealing with science education is nonexistant. The ability is more closely allied with the intellectual domain and requires a breakdown into meaningful factors before further advances can be expected. Because problem solving has failed to signify an isolated ability, studies attempting to contribute to proper methodology required for development of the ability have frequently produced seemingly contradictory results.

Although arrangement of learning activities appears to have some influence on the general abilities in question, specifics in methodology for desired behavioral development are still lacking.

There is also some indication that students enjoy demonstrations or activity centered programs better than text-recitation programs. However, the specific contributions of the methods to scientific abilities have not been identified. Mere manipulation of data, although interesting to many students, appears to have no effect on increasing competencies in science.

Beyond stating that most methods thus far tried, can produce acceptable retention abilities and that a laboratory method is superior for developing laboratory skills, there has been little progress made in the field. Advances in identifying specific processes involved in science problem solving abilities must be defined and techniques for enhancing these isolated behaviors must then be investigated.

PART 2, RESEARCH RELATED TO PROGRAMED INSTRUCTIONAL MATERIALS

This review has been conducted in an attempt to establish an empirical foundation for the general arrangement of learning activities as well as a specific format for the program to be used in the experimental treatment.

The linear or extrinsic program has achieved a higher degree of popularity than the branching or intrinsic program primarily because it is somewhat easier to develop. Thus, a majority of research dealing with programed instructional materials has been conducted through utilization of the linear program.

The theoretical basis of the linear program provides for the inclusion of: small steps or gradual progression to establish complex behaviors, active student participation involving constructed responses and immediate reinforcement of the response. Programs developed in this manner have produced significant changes in student behavior at all levels of learning and in a wide variety of areas. When compared with conventional methods, programed learning materials consistantly produce equivalent performance in shorter periods of time.

Even though a vast amount of research has been conducted during the brief span of time that programed materials have been available, a majority of it has been hampered with common problems. Inadequately prepared and tested programs have frequently been used as experimental treatments. Program sequences have been too short to actually produce significant, measurable behavioral changes, even though such changes may very well exist. And, samples have been relatively small and frequently influenced by the 'Hawthorne Effect.'

STEP SIZE

Early theorists recommended the use of small steps for all students progressing through the linear program. Step size involves the amount of information presented in each frame and the amount of overlap in stimulus elements from frame to frame. It was generally accepted that information, broken into its smallest components, would be most easily assimilated by all learners.

Coulson and Silberman (1961) found significantly better performance, on their criterion instrument, resulting from small steps but reported that a longer period of time was required to progress through the program with smaller steps. Maccoby and Sheffield (reported in Schramm, 1961) obtained their best results with a program using short steps, gradually lengthened as students progressed through the program. Evans, Glaser, and Homme (1960) reported significantly better immediate test performance and better retention with programs using smaller steps. Shay (1961) in a study involving fourth grade students found no relationship between intelligence and step size in so far as his criterion measures could reflect such a difference.

Small amounts of information presented in each frame is apparently the most effecient procedure for all students. However, it is still questionable whether increased performance is due to actual step size or increased time that allows for a greater amount of practice time within the program.

RESPONSE MODE

Opportunity for the learner to respond actively by actually constructing a response is a second internal feature recommended by the psychology laboratories. It has been stated that active responding insures involvement in the learning task, thereby increasing the chance of effective learning.

Neither Coulson and Silberman (1960) or Fry (1960) could find differences on criterion measures that could be attributed to constructed responses when compared with selected responses. Stolurow and Walker (1962) and Lambert, Miller, and Wiley (1962) both used immediate and delayed retention measures but found no significant performance difference resulting from overt versus covert responding. Lambert, Miller, and Wiley did report a significant savings in time by the covert responding groups. Hough (1962) found no difference in constructed, selected or combination response modes.

Krumboltz and Weisman (1962) found that overt responding produced better results on delayed retention tests than did covert responding. Their immediate test results are in complete agreement with other studies reported.

From evidence currently available it may be concluded that overt responding may have some beneficial, long term effect but that such an effect is not immediatly apparent. However, there is a possibility that response mode should not be investigated as an isolated factor but rather in conjunction with prompting and confirmation procedures. If this is true, then current research attempting to investigate interactions of several factors may produce clearly identifiable patterns. It is also possible that in the studies thus far reported, short sequences have built in motivating factors that insure active involvement irrespective of the response mode.

IMMEDIATE REINFORCEMENT

Originally it was thought that some reinforcement of a correct response must occur within five seconds of the response or no learning would occur. Observing that a response was correct, knowledge of results, was thought to be reinforcing or increased the probability of that particular response occuring again. A great deal of criticism directed at the assumption that knowledge of results constituted a type of reinforcement has led to a more frequent use of the word 'confirmation'. Confirmation describes the process of presenting a correct answer to a learner after he has constructed or selected his own response.

An apparent contradiction of knowledge of results acting as an immediate reinforcer is presented in a review of research by Schramm (1962a). Empirical evidence indicates that a correct response by the learner, before progressing to the next frame, is of prime importance. Prompting (clue to the correct response prior to the response) and fading (gradual withdrawal of prompts) appears to produce increased performance on criterion measures. These techniques have been compared with confirmation (reinforcement) procedures and appear to produce significantly superior results, 'depending upon the nature of the task and the procedures.'

Even though immediate knowledge of results has been withheld, the confirmation generally obtained in succeeding frames of a linear program has not been controlled. It is therefore possible to gain knowledge of results in an indirect manner. Because of the nature of the linear program and its ability to slowly increase competencies, it is also possible to conclude that frames are often so easy that the response is relatively well known and needs no further confirmation. It is also possible that interactions of cueing, prompting and confirmation are involved.

FORMAT

Relevant research indicating a preference for a particular method of combining activities with actual programed material is lacking. Recommendations by some authors concerned with panels consisting of diagrams, maps, and/or blocks of information indicate that such inclusions can be inserted almost anywhere in the program.

Convenience would seem to be the primary consideration in this question.

Eigen (1962) recommends the use of the booklet form, programed text, with a vertical format as a practical method of presenting programed materials to the learners. No research has indicated that machine presentation is in any way related to achievement gains resulting from programed instructional materials. (Glaser, Homme, and Evans, 1960; Eigen, 1962; Eigen and Komoski, 1960; and Gotkin and Goldstein, 1962)

Further evidence by Roe, Case and Roe (1962) indicates that logical sequencing of content is preferable to random exposure to material and finally, Silberman and others (1961) and Roe (1962) have demonstrated that branching has no particular advantage over fixed sequence.

The ability to shape behavior through the use of programed instructional materials has been adequately demonstrated in numerous studies. Effective procedures for constructing programed instructional materials with which to develop the desired behaviors have received attention and empirical results are available to substantiate use of a particular style in that construction. The available evidence indicates that a linear, fixed sequence program with small steps, requiring constructed responses by the learner, followed by confirmation of the response is an entirely satisfactory type of program. The specific program utilized in this investigation was also in booklet form with a vertical format and was logically sequenced. Although the superiority of each internal factor as well as the overall combination of relevant factors has not been established at this time, it has been empirically established that such a program will produce results equivalent to any of the other forms considered.

CHAPTER THREE

EXPERIMENTAL DESIGN AND PROCEDURES

A pilot study conducted in the Campus School of State University College (SUC) at Brockport, New York, in the spring of 1963, indicated the feasibility of proceding with the study as originally planned.

SAMPLE

The study was conducted in eighth grade science classes in non-urban junior high schools of Monroe County in New York State. Principals of all junior high schools were invited to a luncheon meeting at SUC at Brockport in May, 1963. An overview of the project was presented to representatives of the eleven schools and a request for their co-operation was extended. Of the schools represented, seven felt it would be possible to extend fullest co-operation of their facilities to the project. Schools unable to participate were involved in other experimental programs, were moving into new buildings, instituting new curriculums or felt that it would be unfair to some of their students to become involved in such a project.

During the summer of 1963 the co-operating schools were asked to supply a list of the eighth grade classes that would be available for the experimental period in the fall of the 63-64 academic year. Only those classes considered to be of average ability, as defined by individual school systems were included. Classes specifically designed for a non-regents program or advanced placement were omitted from the study. From a total of sixty, average eighth grade classes, twelve classes were selected at random and assigned at random to the experimental treatments.

LINEAR PROGRAM

The primary objective of the study involved the ability of eighth grade students to apply scientific principles to problem solving situations. To prepare an experimental treatment that would enhance this ability, specific principles and a pool of problems explained by the principles were outlined. A linear program was then developed to present the principles to eighth grade students. Some of the problems were included in the program to provide practice for students in applying principles to problem situations. Other problems were reserved for a criterion instrument that would be used to evaluate the behavior under examination.

Specific content of the program was centered around energy and work with the various topics of simple machines, electricity, sound, and gravitational force being used to illustrate energy transformations and methods of accomplishing work. Basic scientific principles were developed and supported by selected experiments. In many cases, evidence leading to the statement of a principle was obtained through completion of an experiment. In this manner, experiments became an integral part of the total learning process.

The linear program was developed by first placing frames on individual 3x5 cards and administering the cards to individual students under close observation. Revision, based on difficulties encountered by individuals was completed and the program was administered to four classes, two seventh and two eighth grade classes in the Campus School at SUC at Brockport. The two seventh grade classes were used at this time to insure that reading level and level of item difficulty would be kept well below the minimun anticipated for the eighth grade experimental groups. An initial form of the criterion instrument was administered to this group to investigate the assumption that the program was capable of developing specified behaviors. Final revisions based on the above processes were then undertaken. Program error rate had been reduced to 7 per cent and the criterion instrument indicated that a satisfactory degree of learning had resulted from the program.

The program was edited by Mrs. Floy Delancy, author of a series of reading books for elementary school children, Dr. Jerry Lysaught, co-author of A Guide To Programed Instruction, and Mr. Don Leffler, member of the science department at SUC at Brockport.

During the experimental period, seperate answer sheets were used and students were directed to cross out incorrect answers, reread the statement and write the correct answer in the appropiate space. A vertical format was used with a mask covering items and answers on any one page. Students would place the mask over the page, covering items still to be completed. After constructing an answer, he would move the mask down the page to expose the correct answer and the next frame.

EXPERIMENTAL GROUPS

Five experimental treatments were established to test the hypotheses stated earlier. Each experimental treatment involved student acquisition of new knowledge through participation in the linear program, Energy and Work, prepared by the investigator. A sixth group was established as a control in assessing the influence of a pre-test on a criterion instrument. Experimental treatments were as follows:

1. (EDP) Members within this group progressed through the linear program that was accompanied by an activities booklet. The activities booklet contained specific directions for performing seventy-five experiments. Experiments were designed to present information essential in promoting a thorough understanding of the scientific principles presented in the program. At appropiate places in the linear program the student would be directed to turn to the activities booklet, perform the indicated experiment and then return to the program proper. Each experiment required at least one response, often two or more responses were required, involving recording of data

or drawing of a conclusion. Correct answers were given in the program and would be checked as the student returned to the program. Each student in this group had an experimental kit containing all the necessary equipment for completing the required activities.

2. (Read) Group two was identical to group one in all respects except that the activities booklet contained descriptions of the experiments rather than directions for performing them. Diagrams and verbal directions were given and students were required to answer precisely the same questions as group one. Responses to activities in group two were based on observations of a diagram and interpretation of a verbal description.

3. (Dem) Group three students were directed to ignore all reference to the activity booklets. They were told that rather than reading about experiments they would be able to observe their teacher perform several experiments at the beginning of each period. The later portion of each period would then be devoted to work on individual programs. Again, students were required to make precisely the same responses to activities as group one and two but these responses were based on observations of a teacher demonstration.

4. (EBP) Group four performed all experiments before progressing through the program. Students used the same booklets as group one, had identical experimental kits, constructed identical responses but completed all seventy-

five experiments before doing any work in the programed booklet.

5. (EAP) Group five was similar to group four except that students progressed through the program prior to completing the experiments. Again all responses were identical to other groups.

6. Group six was included for the purpose of investigating effect of the Energy and Work pre-test on the same instrument also used as a post-test. Group six was identical to treatment two (Read) with the exception that it did not have the Energy and Work pre-test.

Because groups four and five did not have access to the program while they were performing the experiments, the correct responses were provided on two pages in the back of the activities booklet. Upon completion of an experiment and accompanying responses, the student would turn to the last page to find the correct answer.

The twelve experimental classes selected at random for participation in the experiment were subdivided into two groups. Six classes were placed at random in the six experimental groups and designated as the first round group. This group began work during the first week of school and completed work during the middle of October. The remaining six classes, randomly assigned to the six experimental groups, were designated as the second round group and spent the period from early October to middle November in working through the experimental treatment.

Before the experiment started, teachers were instructed to announce to students that they were going to learn science in a manner slightly different from that to which they were normally accustomed. The students were told that they would be tested on the material and that marks would count toward report card grades. Students were also instructed to work at their own rate. Teachers were instructed to provide assistance to individuals only when mechanical deficiencies in the program or experimental kits demanded special attention.

EVALUATION INSTRUMENTS

Controls for the covariance analyses were obtained through the use of three pre-tests. An Energy and Work test designed specifically for use with this investigation was administered prior to the experimental treatments. This test was developed for the purpose of measuring student ability to apply scientific principles about energy and work to problem situations not previously encountered by the students. Form A of Sequential Tests of Educational Progress - Science (STEP) was used in an attempt to control for general science problem solving ability.

The third set of tests were administered upon the recommendations from Dr. J.P. Guilford. Three batteries of the Guilford-Zimmerman Aptitude Survey were administered to establish a control for specific intellectual factors. The three batteries: Verbal Comprehension, General

Reasoning, and Spatial Visualition were administered because of their apparent relevance to the terminal behaviors.

The two criterion instruments administered as post-tests were: STEP - Science, Form B and the same Energy and Work test that was administered as a pre-test.

COLLECTION AND RECORDING OF DATA

Pre-tests were administered immediately prior to the experimental treatments. Testing required five and one-half class periods. Each group began work on the programed material as soon as all members in the group completed the pre-tests.

Post-tests were not administered until all members of a particular class had completed the experimental treatment. Exceptions to this procedure were allowed when one or two members within a class were obviously going to consume a considerable amount of extra time. Such individuals were dropped from the experiment and were not given class time to complete the program. Students who finished early were encouraged to bring library books to class to occupy their time while classmates were completing the designated work.

Answers to all tests were recorded on seperate answer sheets and were hand scored.

Data from program answer sheets cannot be compared because students had access to correct answers throughout the program. Error rates or specific errors can be analyzed only when response conditions are more precisely controlled. For this reason, no attempt was made to collect data with respect to specific responses.

Failure to follow directions by a number of individuals in recording starting time and completion time prevented any comparisons of length of time taken by various groups to complete experimental treatments.

STATISTICAL PROCEDURES

Post-test comparisons were made between groups one, two and three (method of receiving supporting evidence leading to development of understanding of scientific principles). Post-test comparisons were also made between groups one, four and five (temporal relationship of activities and program participation). Both first and second round groups were combined for purposes of these comparisons. Analysis of covariance was selected as the appropriate statistical test of the hypotheses concerned with these comparisons.

A t-ratio for matched individuals was used to measure the statistical significance of gain in ability of applying scientific principles as measured by the Energy and Work test.

CHAPTER FOUR

RESULTS

All statistical techniques used in analysis of data are commonly used procedures. Analysis of covariance follows the pattern established by Edwards (1960). The specific analysis was carried out by an IBM 1620 computer on a Fortran Program written by Dr. P. Lohnes of State University of New York at Buffalo (SUNYB). Pearson Product Correlations were computed by the same machine on a program written by Mr. Howard English of SUNYB. t-ratios for matched students (Edwards, 1960) were computed on a Marchant desk calcuator.

Means and standard deviations of the three pre-tests, for the five main experimental groups are presented in table 1. It may be noted that initially, the groups appear quite different on both the Guilford-Zimmerman Aptittude Survey (G-Z) and the Sequential Test of Educational Progress (STEP). Theoretically, the initial group differences are statistically controlled when a covariance analysis is used to analyze post-test scores. The Energy and Work Test (E-W), designed especially for use with this study, indicates a more even distribution of scores for the five groups.

The effectiveness of the pre-test measures, as controls in the analysis of covariance technique, obtains supporting evidence from data presented in table 2. In those pre-tests where a wide range of abilities, among group means, is apparent (table 1), correlations with post-test scores are rather high. On the other hand, the E-W pre-test scores are correlated least with their post-test counterpart and show the least initial variability.

table 1

Means and Standard Deviations of Five Eighth Grade Experimental Groups on Three Tests Administered Prior to Experimental Treatment.

Group	N	G-Z		E-W		STEP-A	
		M	SD	M	SD	M	SD
1	44	13.59	8.46	10.68	2.64	32.66	8.26
2	50	22.80	10.83	9.98	3.48	39.60	7.74
3	46	16.79	9.91	10.79	3.30	35.32	7.83
4	52	22.27	12.14	8.83	4.10	36.52	11.33
5	53	19.68	9.63	10.19	3.39	39.91	6.88

table 2

Pearson Product r of Control Variables with Criterion Variables

		Group				
Control	Criterion	1	2	3	4	5
STEP-A	STEP-B	.483	.825	.591	.739	.753
G-Z	STEP-B	.219	.745	.478	.368	.545
E-W	E-W	.174	.466	.537	.148	.131
G-Z	E-W	.328	.666	.453	.291	.467

Because the same Energy and Work test, used to evaluate ability to apply scientific principles to problem solving situations, was administered as both a pre- and a post-test, it was necessary to assume that there was little or no influence of the pre-test on the post-test. A test of this assumption was accomplished by comparing identical experimental treatments administered to two groups, one taking the pre-test, the other not taking the pre-test. An analysis of covariance, with Guilford-Zimmerman Aptittude scores as a control, was then applied to the E-W post-test scores. An adjusted F-ratio of .3510 verified the tenability of assuming that the pre-test had no influence upon the post-test.

The first five hypotheses were concerned with the effectiveness of each of the experimental treatments in producing significant gains in the specific ability chosen for consideration in this study. This ability has been measured by the E-W instrument designed especially for use in this study.(Standardizing procedures for this instrument are presented in Appendix IV.) t-ratio for matched students has been used as the appropiate statistical test of the null hypotheses concerned with gain in the specific ability. Results of this test for each of the five experimental treatments are presented in table 3. It may be observed, as commonly encountered with programed instructional materials, that significant gains in ability have been produced.

table 3

Gain and t-ratio for E-W Pre- and Post-test

Group	Gain	t
1	2.87	5.70**
2	5.68	10.18**
3	3.96	6.46**
4	5.90	11.02**
5	4.10	9.39**

** Significant at the .01 level.

The covariance analysis that has been used as the appropiate statistical test for the remaining hypotheses is based on the assumption that regression lines within groups are parallel within limits of random sampling. The tenability of this assumption has been statistically verified in each of the analyses reported. A second, less critical assumption of homogeniety of variance has not been satisfied in all cases. Bartlett's F has been presented along with the unadjusted criterion means. Where homogeniety of variance has not been statistically satisfied, the .01 level of confidence has been used as the upper limit for rejection of the hypothesis.

Because of the obvious differences in criterion means, where any differences exist, a posteriori techniques have not been applied for the purpose of determining specific, significant differences. Such differences may be readily determined by inspection.

Hypothesis #6 is concerned with the comparative effectiveness of the three methods of presenting experimental evidence on the specific ability in question. The Energy and Work instrument was designed to measure application of specific principles about energy and work to specific problems in that area. When scores resulting from this instrument were used as the criteria, two appropiate controls for adjusting means were available. The E-W pre-test and the G-Z scores were used independantly to control for initial group differences. Results of these analyses are presented in table 4.

table 4

Method of Presenting Laboratory Type Evidence

Results of E-W Post-Test Based on Covariance Analysis when Post-Test Means are Adjusted by E-W Pre-Test and G-Z Scores

		Criterion			
Group	Control	M	SD	M'	
1 (EDP)		13.55	3.37	13.51	
2 (Read)	E-W	15.66	2.62	15.74	
3 (Dem)		14.83	4.37	14.78	
		F=4.273		F'=4.735	NS
		Bartlett's F=12.197			
1 (EDP)		13.55	3.37	14.11	
2 (Read)	G-Z	15.66	2.62	15.02	
3 (Dem)		14.83	4.37	14.98	
		F=4.273		F'=1.026	NS
		Bartlett's F=12.197			

Failing to approach significance (at the .01 level of confidence required because of failure to meet homogeniety of variance specifications) it may be observed that method of presenting experimental evidence has no effect on ability to apply the scientific principles developed. Non-significant differences are obtained when the Energy and Work post-test scores are controlled by either of the pre-test measures available. However, post-test means do favor reading over seeing a teacher demonstrate which in turn is favored over active participation in laboratory activities within the program.

Hypothesis # 7, effect of temporal relationship of program content to participation in laboratory activities on the specific ability as measured by the Energy and Work test, could be statistically evaluated by means of the two controls available. Results of the Energy and Work post-test, controlled independantly by Guilford-Zimmerman Aptittude scores and Energy and Work pre-test scores are presented in table 5.

In one instance only, is there a significant difference among experimental treatments when Energy and Work test scores were compared. This difference in temporal relationship of content to active participation occured when using the same Energy and Work test as the covariat control. Performing activities prior to progressing through the program is apparently the most effecient procedure for developing competence in the specific ability under consideration.

table 5

Temporal Relationship of Program Content to Participation in Laboratory Activities

Results of E-W Post-Test Based on Covariance Analysis when Post-Test Means are Adjusted by E-W Pre-Test and G-Z Scores

		Criterion		
Group	Control	M	SD	M'
1 (EDP)		13.55	3.37	13.19
4 (EBP)	E-W	14.73	3.58	15.17
5 (EAP)		14.28	3.59	14.14
		F=1.360		F'=4.392*
		Bartlett's F=.221		
1 (EDP)		13.55	3.37	14.45
4 (EBP)	G-Z	14.73	3.58	14.12
5 (EAP)		14.28	3.59	14.12
		F=1.306		F'=.164 NS
		Bartlett's F=.221		

* Significant at the .05 level

When specific application is used as the criteria, performance of activities during progress through the program was the least effective technique used in the investigation. Reading was slightly favored, not significantly however, and performance of activities prior to program participation was significantly superior. Seeing a teacher demonstrate the activities and performing the activities after progressing through the program fall somewhere in the medium range of effectiveness.

Table 6 presents results of the two statistical tests used to evaluate the effect method of receiving evidence about laboratory type exercises has on general science problem solving ability as measured by STEP, form B. (Hypothesis #8) STEP, form A has been used as a control for adjusting means in the covariance analysis in the first test in the table while G-Z scores have been used as the control in the second test.

table 6

Method of Presenting Laboratory Type Evidence

Results of STEP, Form B Based on Covariance Analysis
when Post-Test Means are Adjusted by STEP, Form A and
G-Z Scores

		Criterion		
Group	Control	M	SD	M'
1 (EDP)		27.16	7.08	29.11
2 (Read)	STEP-A	37.38	6.58	35.29
3 (Dem)		33.06	7.33	33.46
		F=25.069		F'=15.008**
		Bartlett's F=.562		
1 (EDP)		27.16	7.08	28.35
2 (Read)	G-Z	37.38	6.58	36.04
3 (Dem)		33.06	7.33	33.37
		F=25.069		F'=14.833**
		Bartlett's F=.562		

** Significant at the .01 level

When general problem solving ability is used as the criteria, actual performance of activities appears to be a severe detriment to achievement. Reading about the activities as well as observing a teacher demonstrate them are both superior techniques. The significance of this superiority far exceeds the probability of a chance occurance due to sampling errors. Reading is only slightly favored over observation of the activities in the teacher demonstration method.

Looking at only these results, one might be influenced to reject the use of active participation in laboratory exercises by eighth grade students when development of general problem solving ability is the major goal. However, statistical results of the test of hypothesis #9 provide equally strong indications that there are significant differences in the temporal relationship of active participation in laboratory exercises to content acquisition, Performance of activities during progress through the program (procedure used in the method comparisons) was consistantly the least effective procedure.

Results of analyzing the effect of temporal relationship of program content to active participation on general science problem solving ability are presented in table 7. The two statistical tests presented have utilized both controls available for adjusting criterion means in the covariance analysis. The means in the first statistical test are controlled by STEP-A while those in the second statistical test are controlled by G-Z scores.

table 7

Temporal Relationship of Program Content to Participation in Laboratory Activities

Results of STEP, Form B Based on Covariance Analysis when Post-Test Means are Adjusted by STEP, Form A and G-Z Scores

			Criterion	
Group	Control	M	SD	M'
1 (EDP)		27.16	7.08	29.77
4 (EBP)	STEP-A	31.46	10.99	31.50
5 (EAP)		36.21	6.96	34.00
		F=13.352		F'=5.218**
		Bartlett's F=14.006		
1 (EDP)				
4 (EBP)	G-Z	S3 = 6.795** Assumption of parallel regression lines within groups is untenable.		
5 (EAP)				

** Significant at the .01 level

CHAPTER FIVE

CONCLUSIONS

This project was initiated with the intention of discovering how presentation of selected variables, within programed instructional materials, would effect the ability of eighth grade students in approaching problem solving situations in science. Nine null hypotheses were generated from the specific variables incorporated in the objectives of the study. Results of statistical tests as they apply to each of the nine null hypotheses were as follows:

1. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials which incorporate active participation in laboratory exercises throughout the program.

Rejected $P < .01$

2. There is no significant gain in student ability to apply scientific principles to problem situations as a result of reading about laboratory exercises as they progress through programed materials.

Rejected $P < .01$

3. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials accompanied by teacher demonstrations.

Rejected $P < .01$

4. There is no significant gain in student ability to apply scientific principles to problem situations as a result of participating in laboratory exercises and then progressing through programed materials.

Rejected $P < .01$

5. There is no significant gain in student ability to apply scientific principles to problem situations as a result of progressing through programed materials and then participating in laboratory exercises.

Rejected $P < .01$

6. There is no significant difference in student ability to apply scientific principles to problem situations, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises, through descriptions or demonstrations.

Fail to reject

7. There is no significant difference in student ability to apply scientific principles to problem situations, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises before, during, or after progressing through programed materials.

Rejected $P < .01$

8. There is no significant difference in student general science problem solving ability, regardless of whether experimental evidence is obtained by means of participating in laboratory exercises, through descriptions or demonstrations.

Rejected $P < .01$

9. There is no significant difference in student general science problem solving ability regardless of whether experimental evidence is obtained by means of participating in laboratory exercises before, during or after progressing through programed materials.

Rejected $P < .01$

DISCUSSION

Significant gains in the specific ability under consideration were produced by each of the five experimental treatments used in the study. This finding has been consistantly demonstrated with programed instructional materials in two types of situations, comparisons with traditional control groups as well as comparisons resulting from pre- to post-test gains.

The ability being measured in this study would appear to be dependant upon retention of factual information and understanding of the principles presented. Thus, it may reasonably be concluded that retention and understanding, on the part of eighth grade students, was enhanced by each of the five experimental treatments.

Failure of the Energy and Work criterion instrument to discriminate between experimental treatments involving method comparisons (table 4) may be taken as an indication that no differences in method, for promoting this ability, did exist or that the instrument was insensative to such differences. However, the later conclusion would appear less tenable in light of the fact that the E-W instrument was sensative to other differences for which it was designed to detect. The statistically significant difference obtained through use of the E-W instrument (table 5) indicated that completion of activities prior to program participation was the most effective procedure for developing the specific ability in question. It would seem that two factors, one negative and one positive, contribute to the success of this arrangement: first, the awkwardness introduced by the necessity of continually turning to the activity booklet to perform experiments reduced effeciency and secondly, performance of the laboratory exercises followed by a thorough clarification of these experiences as developed within the program, increased effeciency. This conclusion must be limited to the situation wherein the specific principles presented are being applied to problems based on understanding of those principles.

From the findings in table 4 and 6, it may be noted that effectiveness of a procedure varies with the criterion instrument being used. This has long been known and even early studies discriminated between behavioral or manipulative criteria and verbal skills. However, the two criteria used in this study, both verbal, appear to be quite similar in nature. One, STEP is defined as a general problem solving measure while the other, more specific, measures ability to apply scientific principles to problem situations. A heuristic examination of the two variables would seem to indicate that application is a subcategory of the more general problem solving ability. Thus, application of specific principles may very well constitute only one minor aspect of general problem solving ability.

In terms of general science problem solving ability, reading about activities is far superior to actually performing them. However, when a more specific skill within the realm of the general ability is investigated, it is discovered that reading is more nearly equal to the effect produced by actual participation in laboratory experiences. This being the case, one might then expect to find, at the other extreme, an aspect of general problem solving ability that is influenced most effeciently by active participation in laboratory experiences. General, verbal science problem solving ability may be located at one end of a continuum, effected to the greatest degree by verbal acquisition of knowledge. Moving down and out into the two main branches of the continuum, one might expect to find an increasing influence by active participation and decreasing influence from verbalization. The specific ability chosen in this study is very nearly equally effected by both reading and active participation and would be placed near the middle of the continuum. Thus hypothetically, as the other end of the continuum is approached, the location of two groups of isolated aspects of problem solving ability can be anticipated. One group will be influenced primarily by verbal acquisition of knowledge while the other group will be influenced extensively by concrete experiences.

Thus, the results of this study suggest the feasibility of anticipating the identification and isolation of factors somewhat similar to those originally proposed by Guilford (1960). Such factors may very well be influenced exclusively by either concrete experiences or by verbal acquisition of knowledge. This is not to suggest that laboratory participation is most effective for developing laboratory skills but rather that laboratory participation has a significant influence upon some factor of problem solving ability.

From the results presented in table 7, it was concluded that the group performing experiments after progressing through the program did significantly better on the general problem solving measure than did either of the other groups. Thus, a definite indication of the importance of considering the relationship between performance of activities and content acquisition is provided. A verbal development of the principles being presented, followed by active participation in laboratory exercises is the most effective procedure for developing general problem solving abilities. It would appear that the more complete development of verbal knowledge, prior to active participation, enables eighth grade students to benefit most significantly from the participation in concrete experiences. A comparison of this particular procedure, with other methods, i.e. observing, reading, may very well have resulted in no significant difference in method.

When the program was constructed, activities were inserted when it was thought that results obtained from participation in them would contribute to the scientific principles being developed. Frames immediatly following the activities utilized results in developing understanding of the principles. Under these circumstances, at the eighth grade level, when general problem solving ability is used as the criteria, it appears that most significant scores can be obtained if students progress through the entire program before starting to perform these activities.

These temporal effects of program content and participation in laboratory exercises may be adequately accounted for by turning to the work of Piaget. His findings seem to indicate that the ability to form abstractions from the concrete world is a definite developmental task. Thus, the extent to which verbal abilities may result from manipulation of the concrete world would depend upon the developmental stage of the learner. Results indicate that the ability to verbalize principles resulting from participation in certain activities illustrative of these principles is significantly increased by exposure to programed content prior to active involvement. Evidently, the entire verbal program, prior to data manipulation, presents enough of a developmental set to significantly increase interpretation of the concrete experiences by eighth grade students.

Thus, general ability, as opposed to a specific ability appears to be enhanced if some direction is provided prior to participation in original data collection. A higher degree of ability to generalize is acquired in this manner as evidenced by the superior performance on the general science problem solving measure. However, no similar superiority was evident on the specific application measure. As mentioned earlier, specific application appears to gain greatest reinforcement through data collection followed by verbal clarification of the experiences.

RECOMMENDATIONS AND LIMITATIONS

Active science experimentation on the part of junior high students is being recommended by a wide variety of agencies. There is little evidence, however, indicating that such a procedure within programed instructional materials contributes to any known abilities within the scope of science education at the junior high level. A further qualification, that science experimentation used in this project was of the 'cookbook' variety must also be imposed.

The generalization of this statement to all science instructional situations must be made with caution. The ability of a teacher to point out certain aspects of a concrete situation, to adjust to the concrete situation, and to encourage student discussion and questions may very well be what is needed to insure appropiate data interpretation and ability to effectively verbalize concrete situtions.

Little application can be made in terms of inquiry approaches to science instruction. In such approaches it is usually assumed that a student is performing an experiment for an express purpose, often internalized and such participation is going to provide specified information. The ability to verbalize as a result of this form of participation may be enhanced by the predetermined recognition of possible alternatives.

Further research, with refined programed materials, that takes into account the necessary developmental aspects reouired for adequate verbalization of concrete situations is recommended. Secondly, it is strongly recommended that evaluation procedures be refined to account for the principle compenents of problem solving ability. Until investigators become more cognizant of the precise relationships between intended effect and specific outcome factors, further methodology studies can be expected to reveal similar, conflicting results, depending upon the choice of criterion instruments. Because of the control over behavior, afforded by programed instructional materials, it is recommended that these materials be used as a vehicle for further investigations of these variables.

Two possible limitations become apparent in evaluating test data. First, it may be noted that pre-test means on the STEP - A instrument are in the precise numerical order as the STEP - B post-test means. If complete confidence can be placed in the covariance analysis and its statistical ability to account for obvious initial differences, then this observation creates no problem. Secondly, failure of two unadjusted group variances to meet homogeniety of variance requirements places a small strain on basic assumptions. However, this becomes much less critical if confidence limits, for rejecting the null hypothesis are lowered to the .01 level.

Other potential limiting factors became apparent as a result of observations of the experimental groups during their progress through the program. In two of the classes, group #1 and group #4, discipline appeared to be lax. If the basic assumption, lack of teacher influence on groups when programed instructional materials are being utilized, holds true, then no problem arises. This stúdy was designed to limit this factor by selecting, at random, two eighth grade classes to participate in each experimental treatment. Both classes were then grouped together for purposes of analyzing data. It is possible that further investigations, of a similar nature, might profitably use several classes in each experimental treatment.

SUMMARY

The effect of three methods of presenting laboratory evidence within programed materials has been evaluated in terms of eighth grade student, general science problem solving ability and a specific ability defined as application of specific principles to problem situations. A second dependant variable, that of the temporal relationship between active laboratory participation and program participation has also been investigated.

A search of available literature revealed that only recently has general science problem solving ability become a frequently used criteria. However, effective methods of promoting the ability have not been empirically established primarily because the term is too vague and does not represent an isolated, identifiable ability. Empirical evidence supporting the utilization of a particular style in constructing a program for use in presenting science content was found. Programed booklets were used with a linear, fixed sequence program. Immediate confirmation was provided for the constructed responses required at each frame.

A total of 296 eighth grade students in twelve randomally selected, non-specialized classes from non-urban junior high schools in Monroe County (New York State) were involved in the study. Fifty-one of these students, two classes, were in a group designed as a control for the purpose of determining the influence of a specific pre-test on a post-test. The remaining ten classes, 245 students, were randomally assigned to five experimental treatments. Two eighth grade classes were exposed to one of the following situations:

1. (EDP) Students in this group actively participated in laboratory exercises during their progress through the program. N = 44
2. (Read) Students in this group read thorough descriptions of the laboratory exercises during their progress through the program. N = 50
3. (Dem) Students in this group observed a teacher

demonstrate the laboratory exercises during their progress through the program. N = 46

4. (EBP) Students in this group completed all laboratory exercises before beginning work on the program. N = 52

5. (EAP) Students in this group completed all laboratory exercises after they had completed the program. N = 53

The program consisted of roughly 700 frames dealing with concepts in the area of energy and work and was identical for all experimental groups. The seventy-five experiments were in a seperate activities booklet.

All five experimental methods produced significant increases in the specific ability of applying scientific principles as measured by the Energy and Work instrument. Gain scores from pre- to post-test measures were evaluated by a t-ratio for matched students.

The relative effectiveness of the procedures utilized varied with the type of criterion instrument used. General science problem solving ability, as measured by Sequential Test of Educational Progress - Science was influenced most effeciently by reading about activities. Seeing a teacher demonstrate the same activities was slightly less effective and active participation in laboratory exercises during progress through the program was the least effective procedure used. No significant difference in method could be found when the specific ability of applying scientific principles to problem situations was being evaluated.

Significant differences in temporal relationships were found with participation in laboratory exercises during progress through the program consistantly being the least effective procedure used. All multigroup comparisons were analyzed by means of a covariance analysis.

It was concluded that the effectiveness of various forms of acquiring experimental evidence supporting the development of scientific principles, within programed instructional materials, varies with the type of criterion instrument being used. Results of this study indicate the tenability of further investigations to discover effects upon component factors within the realm of problem solving ability as well as the relationship and identification of developmental stages and their effedt on ability to acquire verbal abilities from concrete situations.

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APPENDIX I

Written Instructions Given to Experimental Groups Prior to their Work in the Programed Text and/or Activities Booklet

All Groups - Instructions with programed text.

Directions:

You are ready to learn about energy, work and some of the many factors associated with these aspects of science in our daily lives. The method by which you are going to learn is called, 'programed instruction'. Because this is a new technique of learning, here are a few hints that will help you score well on the tests following your work on the program.

1. Place the piece of cardboard over page one, so that only statement #1 is showing. Read the statement carefully and write the missing word in the first blank, #1 on your answer sheet.
2. Move the cardboard down the page until you find the correct answer to #1. Compare the correct answer with your answer.
3. If your answer is the same, or nearly the same as the correct one given, you may repeat the same process with #2, and so on with #3, #4, etc.
4. If your answer was very different from the correct one given, cross out your answer, do not erase, reread the statement and write the correct answer just to the right of your incorrect answer. You may then go on to #2.
5. The correct answers always follow each statement and

it would be very easy for you to merely copy these answers on your answer sheet. However, it has been found that students who write their answers before looking at the correct ones, do much better on tests taken after they have completed work on the program. You will learn best if you try to supply the missing words to each statement before looking at the correct answer and carefully rereading each statement that you 'miss'. Remember, if you miss a word, cross it out, reread the statement and write the correct word in the second blank to the right of the incorrect answer on your answer sheet.

Demonstration Group - Additional directions with programed text.

Throughout the program you will find statements such as, "turn to activity #1 for further information." You may ignore these statements and the answers directly following them. Instead of looking at activities in a booklet, your teacher will perform several experiments at the beginning of each period and you will record your answers to questions, about these experiments, on a seperate answer sheet.

Group Performing Experiments After Program - Additional directions with programed text.

Throughout the program you will find statements such as, "turn to activity #1 for further information," You may ignore these statements and answers directly following them. Instead of performing experiments at this time you will do all seventy-five at one time, after you have finished the program.

Group Performing Experiments During Program - Activities Booklet.

The pages in this booklet contain a series of experiments that you will perform as you are working through the program. When working with the program you will come to a statement, "turn to activity #1 for further information." At this point you will turn to this booklet, read the experiment carefully, do as you are directed and answer the question or questions included with the experiment. The correct answers will be found in the program immediatly below the direction, "turn to activity # ..." Check your answer as you would if you were working through the program and then go on to the next statement in the program. Some of the experiments may appear very easy but it is important to complete each one, for they build up to several more difficult activities and it is essential that you understand each step in the development.

All the equipment you will need may be found in your experimental kit. Please be careful with this material because other students will be using it after you have completed your work. After you have finished with the kit, take apart all of the devices you have constructed.

Group Reading About Experiments During Program - Activities Booklet.

The pages in this booklet contain a series of descriptions of experiments that you might perform if you had the proper equipment. When working with the program you will come to a statement, "turn to activity #1 for further information." At this point you will turn to this booklet, read the description and answer the questions included with the description. The correct answers will be found, in the program, immediatly below the direction, "turn to activity ..." Check your answer as you would if you were working through the program and then go on to the next statement in the program. Some of the descriptions may appear very simple but it is important to read each carefully, for they build up to several more difficult activities and it is essential that you understand each step in the development.

APPENDIX II

A Page Selected At Random From The Linear Program, Energy And Work

35. The amount of energy required will not be reduced by using simple machines. Because of friction present in all machines it is probable that more __________ would be required than if a machine were not being used.

35. energy

36. Turn to activity #14 for further information.

36. a. 2 - 3 ozs b. 2 - 3 ozs

37. Because a 4 oz weight is being lifted with only 2 - 3 ozs of force, we say that we have gained ________.

37. force

38. When using this second type of level, the amount of __________ required to lift the weight is decreased so we may say that we have gained force.

38. force

39. If the amount of force is decreased, the distance through which the force must move will be __________ and we will have lost distance.

39. increased

40. Turn to activity # 15 for further information.

40. a. 1½ - 2 ozs b. 4½ - 5 ozs

41. The greatest gain in force is obtained when the weight is (nearer to/further away from) the fulcrum.

41. nearer to

42. Turn to activity #16 for further information.

42. 3 in.

APPENDIX III

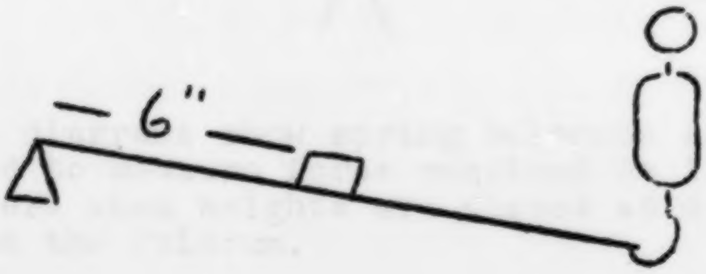
Activities to Accompany The Randomally Selected Page Taken From The Linear Program, Energy and Work

A. Directions for performing the specific experiments.

14. Another kind of level may be made if the fulcrum is placed at one end of the lever, as shown in the diagram. Place a 4 oz. weight, 6" from the fulcrum and lift the free end of the lever with the spring balance.

a. What is the reading on the spring balance? ________

b. Force required to lift the weight is _________.

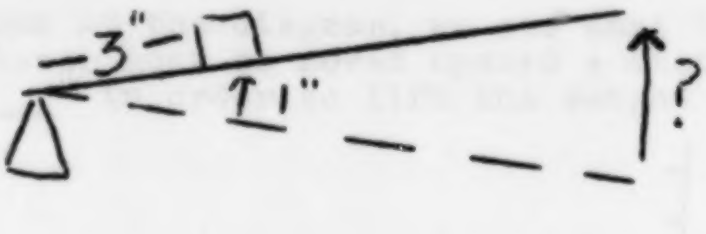


15. Repeat activity #14 and find the force required to lift the two lead weights (6 ozs.) when:

a. the weight is 2" from the fulcrum.______

b. the weight is 8" from the fulcrum. _____

16. Repeat activity #14 butthis time place the 4 oz weight, 3" from the fulcrum. In order to move the weight upward a distance of 1", the free end of the lever must be moved upward a distance of ______".

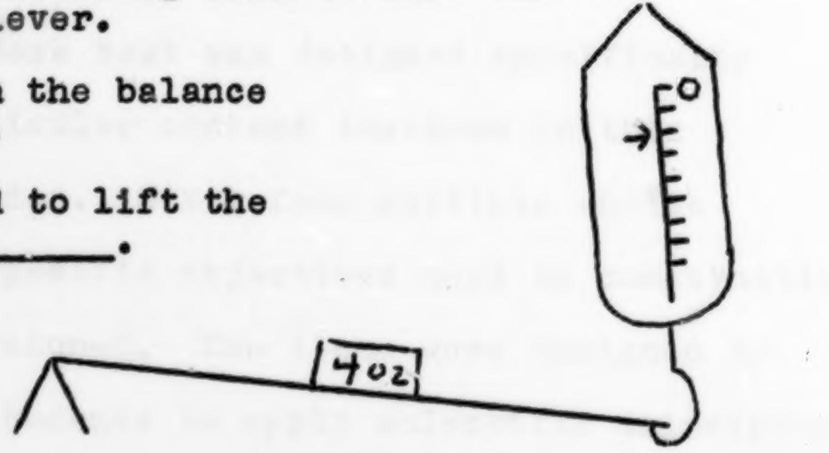


B. Descriptions of the experiments.

14. Another kind of lever is shown in the diagram below. The weight is 6" from the fulcrum and a spring balance is being used to lift the free end of the lever.

    a. The reading on the balance is ________.

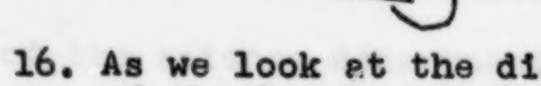
    b. Force required to lift the weight is ________.

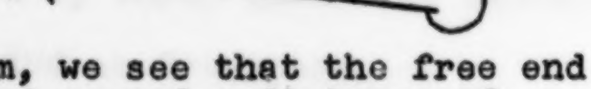


15. The diagrams show spring balances as they are being used to measure force required to lift weights and levers when weights are placed at different distances from the fulcrum.

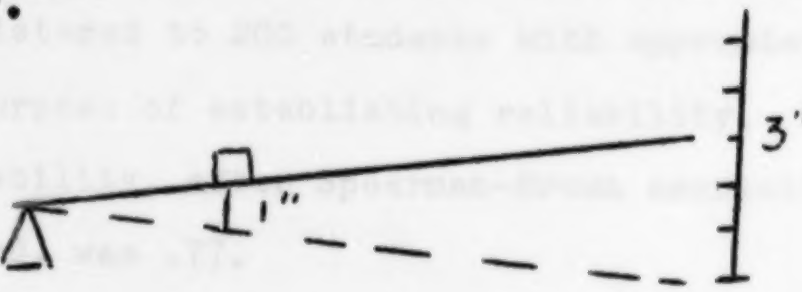
    a. The force required to lift the weight when it is 2" from the fulcrum is ________.

    b. The force required to lift the weight when it is 8" from the fulcrum is ________.





16. As we look at the diagram, we see that the free end of the lever must be moved upward a distance of ________" in order to lift the weight a distance of 1".



APPENDIX IV

Standardization Procedures for the Energy and Work Test

The Energy and Work test was designed specifically for use with the particular content involved in this particular investigation. Sixty-four multiple choice items, based on the specific objectives used in constructing the program, were developed. The items were designed to evaluate ability of students to apply scientific principles presented in the program to problems not encountered in the program.

The sixty-four items were administered to 400 junior high students with science content background similar to those completing the programed sequence. Degree of difficulty for each item was determined and only those items answered correctly by 25 - 75 per cent of the students were retained. Degree of discrimination for each item was determined and items with a Pearson r index of .30 or higher were retained. Face validity of the items was then established by three qualified members of the science department of SUC at Brockport.

The final instrument, containing twenty-eight items, was administered to 200 students with appropiate backgrounds for the purpose of establishing reliability. The split-half reliability, after Spearman-Brown correction formula was applied, was .77.

APPENDIX V

Energy and Work Test

1. Friction will be reduced if:

   a. the two surfaces invloved are made more smooth.
   b. a simple machine is used.
   c. an ineffecient machine.is used.
   d. the two surfaces involved are made more rough.

2. Friction may be reduced by the use of:

   a. simple machines.
   b. oil and bearings.
   c. increased force.
   d. rough surfaces.

3. The position of the poles of an electromagnet will depend upon:

   a. the amount of electrical energy in the electromagnet.
   b. the strength of the dry cells.
   c. the direction of flow of electrical energy.
   d. the way in which the wire is wound around the iron core.

4. A permanent magnet is:

   a. in the shape of a bar.
   b. produced by electromagnetic forces.
   c. able to attract all materials.
   d. must be made from a material that is attracted by a magnet.

5. An object must float in water if:

   a. it has a lot of air in it.
   b. it displaces water equal to its weight.
   c. it displaces water equal to its volumn.
   d. water pressure pushes up on the object.

6. When using a simple machine to move a weight against a resistance, we may think of the weight being moved as:

   a. force required.
   b. energy present.
   c. work accomplished.
   d. mechanical advantage.

7. Thunder occurs because:

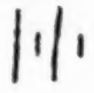
   a. lightning is a form of light and sound energy.
   b. lightning causes air to vibrate.
   c. lightning travels easily through air.
   d. sound travels easily through air.

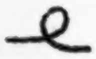
8. It is impossible for work accomplished to equal energy used in a machine because:

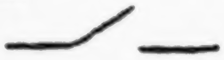
   a. the M.A. cannot be greater than 1.
   b. some friction is present in every machine.
   c. air pressure changes the efficiency of a machine.
   d. energy transformation is not complete.

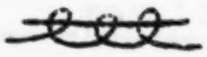
9-10 People concerned with electricity often use diagrams to illustrate various kinds of circuits. Common symbols are frequently used instead of drawing pictures of dry cells, lamps, etc.

Some symbols are:

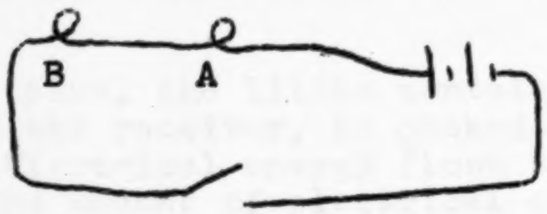
dry cell or source of electricity 

lamp 

switch 

electromagnet 

If we were to make a diagram of a simple complete circuit we would do it in the following fashion.



Questions 9 and 10 are based on the diagram and symbols presented above.

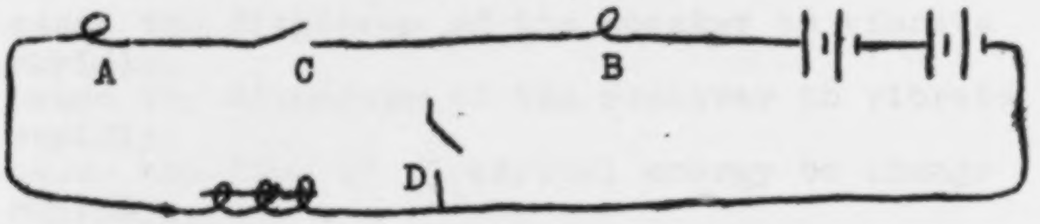
9. The two lamps are attached in a:

   a. series circuit.
   b. parallel circuit.
   c. complete circuit.
   d. none of these.

10. If the switch is closed and lamp A is removed from the socket:

    a. lamp A will light.
    b. lamp B will light.
    c. both lamps will light.
    d. neither lamp will light.

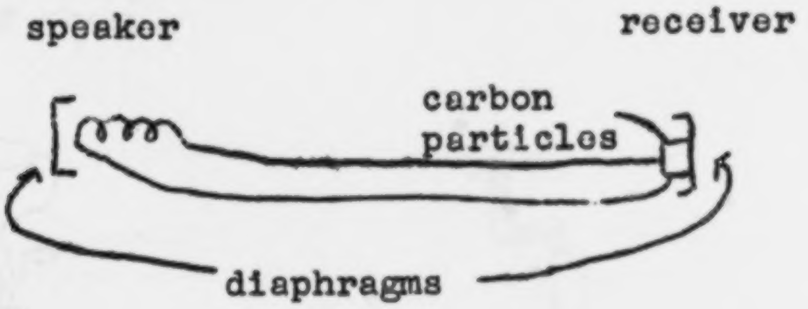
Question 11 is based on the diagram below.



11. If switch D is closed, switch C left open, and both bulbs are left in their sockets:

    a. both lamps and the electromagnet will be operating.
    b. only lamp B and the electromagnet will operate.
    c. only the two lamps will be operating.
    d. only lamp B will be operating.

12-13. A telephone is a modern convenience based on several simple principles dealing with energy and energy transformations. If we were to make a simple diagram of a telephone showing some of the important parts, we would be concerned with the following:



An important part, the little container behind the diaphragm of the receiver, is packed with carbon particles. Electrical energy flows through this container, the amount of electrical energy depends upon the vibrations of the diaphragm. The greater the movement of the diaphragm, the more tightly packed the carbon particles become, and the flow of electrical energy is increased.

Questions 12 and 13 are based on the above information.

12. The receiver is responsible for transforming:

    a. muscular energy to sound energy.
    b. mechanical energy to muscular energy.
    c. sound energy to electrical energy.
    d. electrical energy to mechanical energy.

13. A high pitched sound going into the receiver will:

    a. cause the diaphragm of the speaker to vibrate rapidly.
    b. cause the diaphragm of the receiver to vibrate rapidly.
    c. cause the flow of electrical energy to change rapidly.
    d. all of these.

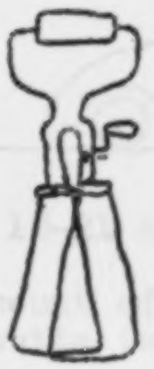
14. A compass is a small magnet which is allowed to turn very freely. One end points north because the Earth has a magnetic force of its own with one pole located near the North pole of the Earth and the other located near the South pole of our Earth.

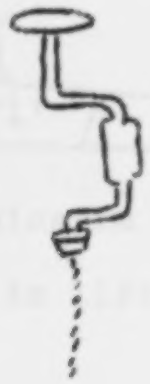
Question 14 is based on the above information.

14. We could make a compass needle by:

    a. hanging a bar magnet so that it could swing freely.
    b. magnetize a needle and allow it to move freely.
    c. make an electromagnet and hang it so it could swing freely.
    d. any of these.

15-16.





Questions 15 - 16 are based on the above diagrams.

15. When we turn the handle of the egg beater we are:

    a. gaining speed because a large gear turns a small gear.
    b. losing speed because a large gear is turning a smaller gear.
    c. gaining speed because the gears are at right angles to each other.
    d. gaining force because the gears are at right angles to each other.

16. The brace and bit is based on the principle of a (an):

    a. lever.
    b. wheel and axle.
    c. gear.
    d. inclined plane.

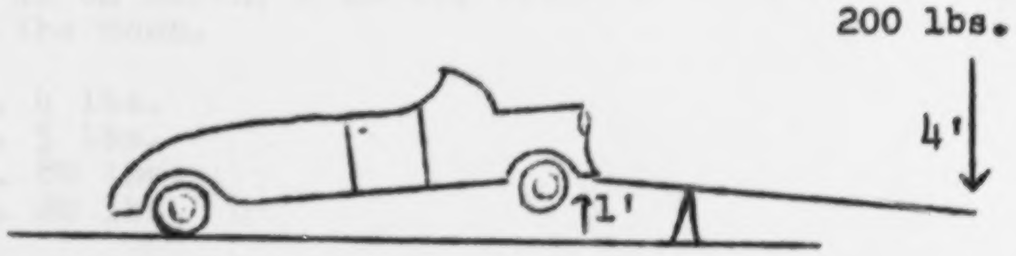
17. A 200 pound boat, capable of displacing 10 cubic feet of water, is placed in water. Water weighs 65 pounds per cubic foot. Each cubic foot of water displaced will supply an upward force of 65 pounds.

Question 17 is based on the information above.

17. The boat will sink when ______ lbs are added to it.

    a. 200
    b. 300
    c. 400
    d. more than 400 lbs.

18-21. A simple machine is being used to lift one corner of a 3,000 pound automobile off the ground so that a tire may be changed.



Questions 18-21 are based on the diagram shown above.

18. The amount of energy required to lift the corner of the automobile is:

    a. 3,000 ft. lbs.
    b. 800 lbs.
    c. 200 ft. lbs.
    d. 800 ft. lbs.

19. The amount of work accomplished when one corner of the automobile is lifted is:

    a. 3,000 ft. lbs.
    b. 200 lbs.
    c. 200 ft. lbs.
    d. 800 ft. lbs.

20. The simple machine being used is:

    a. a 1st class lever.
    b. a 2nd class lever.
    c. a 3rd class lever.
    d. not a lever.

21. Mechanical advantage of the simple machine being used is:

    a. 1
    b. 2
    c. 3
    d. 4

22. Whenever two or more simple machines are somehow combined together to perform work, we have a complex machine. A complex machine will still behave exactly like the different simple machine from which it is made. A bicycle is an example of a complex machine.

22. The wheels of the bicycle turn on an axle. There are small ball bearings between the axle and the wheel which:

    a. are required to gain force.
    b. reduce friction.
    c. allow the gear to turn the wheel more rapidly.
    d. are required to operate the brakes of the bicycle.

23. If gravitational pull on the moon is about $\frac{1}{4}$ of what it is on Earth, a 20 lb. block of lead would weigh, _____ on the moon.

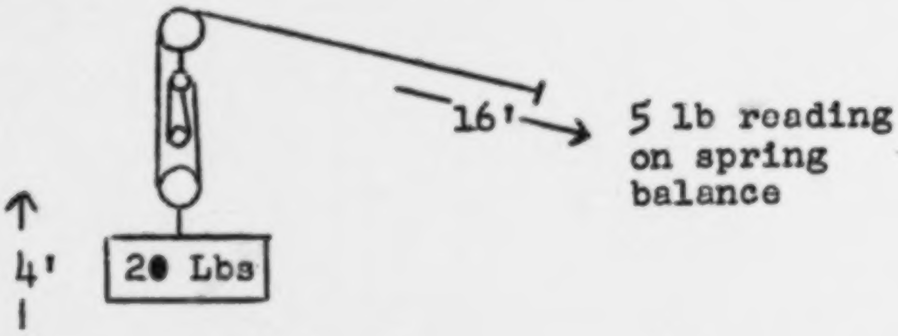
    a. 4 lbs.
    b. 5 lbs.
    c. 80 lbs.
    d. 20 lbs.

24. Horsepower is sometimes used to describe the amount of energy being used or the amount of energy a machine is capable of providing. Horsepower is defined as the amount of energy that can be produced during a specific period of time, usually in one second. Scientists use the figure, 550 ft. lbs. per second as the measurement of 1 horsepower. That is, if a machine is capable of moving 550 lbs, a distance of 1 foot in 1 second, it would have a rating of 1 horsepower.

24. An electric motor moves a 275 lb. object 1 ft. in 1 second. Its horsepower rating would be:

    a. $\frac{1}{4}$
    b. $\frac{1}{2}$
    c. 1
    d. 2

25-27 The simple machine shown in the diagram is a set of pulleys. The various distances parts have moved and the readings that were obtained on a spring balance as a result of the movement, are shown in appropiate places on the diagram.



Questions 25-27 are on the information provided above.

25. The force required to lift the weight, with no friction is:

   a. 5 ft. lbs.
   b. 80 ft. lbs.
   c. 20 lbs.
   d. 5 lbs.

26. The energy required to lift the weight 4' off the table is:

   a. 80 ft. lbs.
   b. 16 ft. lbs.
   c. 80 lbs.
   d. 5 lbs.

27. Actual mechanical advantage of the pulley is:

   a. 1
   b. 2
   c. 3
   d. 4

28. An ideal machine is a machine that has no friction. An ideal machine would be:

   a. effecient
   b. ineffecient
   c. a simple machine
   d. a complex machine